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PRELIMINARY STUDIES OF DETECTION TIME AND OTHER FACTORS INVOLVED IN AEW PERFORMANCE

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Prepared by: Arthur Lefford, Asst. Technical Director for Experimental Psychology

Robert E. Taubman, Assoc. Technical Director

Reviewed by:

Robert L. Chapman, Ph.D., Tech. Director

Renato Contini, Project Director

Approved by:

Harold K Work

Harold K. Work, Ph.D.
Research Director

- -

For the Special Devices Center:

Reviewed for
Human Engineering Branch:

V. J. Sharkey

V. J. Sharkey, Project Engineer
Head, Code 911

Submitted:

Fred W. Fittler Cdr. U.S.N.

for C. S. Rhoads, Technical Director

Approved:

C. V. Gordon

J. R. Ruhsenberger, Captain, USN
Commanding Officer and Director

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I. SUMMARY

1. Purpose

This experiment deals with the effect of increasing the work load on the output of a single operator and PPI console. Work load was increased by increasing the number of targets on the scope face. The information obtained in this study is a necessary preliminary to the evaluation of the Cadillac III CIC system. A rationale for the evaluation of this system is presented.

2. Data

The data for this report were obtained under laboratory conditions which simulated the Cadillac III CIC system in a PO-1W airplane. The targets were presented by means of an electronic target generator. The data were gathered from photographs of the scope picture, recordings of the operators' verbal reports, and direct observation of plotting behavior. The four experimental subjects were naval officers with CIC experience. Each subject was tested four times on four equivalent problems under controlled conditions.

3. Conclusions

a. It was found that detection time for a new target was a positive exponential function of the number of targets on the scope face. With no targets on the scope, the detection time for a new target was found to be, on the average, 0.10 minutes, with 14 targets, 1.35 minutes.

b. The chief findings concerning errors of estimation are given in the table on the following page.

Accuracy of direct estimation of target characteristics is given in terms of relative and absolute errors. Errors considered with respect to both magnitude and direction are called relative errors. Errors considered solely with respect to magnitude are called absolute errors. The mean relative error indicates constant errors of estimation. The standard deviation (S.D.) of the relative errors indicates the consistency of the estimates. The median absolute error indicates the accuracy of the estimates in terms of the absolute error.

Target Characteristic	Relative Error		Absolute Error	
Bearing (degrees)	Mean	0.53	Median*	1.76
	S.D.	2.58	Q_3-Q_1 **	2.16
Range (miles)	Mean	1.85	Median	2.40
	S.D.	2.17	Q_3-Q_1	2.10
Course (degrees)	Mean	1.13	Median	5.83
	S.D.	11.95	Q_3-Q_1	14.06
Speed (knots)	Mean	130	Range	0-350

*The median error represents the mid-point above and below which 50 percent of the errors were observed.

**Q_3-Q_1, the interquartile range, represents the range of the middle 50 percent of the observed errors.

c. When the number of reports made within a minute interval was considered as a function of the running time of the experiment, a cyclical relationship appeared; i.e., about 10 to 12 reports were made per minute. It was also found that the time between successive reports on a given target increases with the number of targets to be reported.

d. The number of plots made per unit time remained constant under varying loads. The average number of plots was found to be 5.26 per minute.

II. SYSTEMS EVALUATION

In the area of human engineering the concept of systems research is relatively new. Definite principles of systems research are still being evolved in the daily work of this and other laboratories. In the sense considered here, a "System" is thought of as a functional organization of men and machines for the accomplishment of some task. In more specific terms the systems to be studied here constitute a functional organization of the CIC personnel and equipment to effect the various stated missions of an airborne CIC.

1. The Functional Elements of a CIC System

Before proceeding to the discussion of how the CIC system may be evaluated, the functional aspects of a CIC system should be considered. These elements may be considered as:

Input - CIC System - Output.

The input into the system includes the following: (1) the intelligence briefing and the operational orders given to the CIC, (2) information obtained through radio communication from command, combat air patrols and liaison, and (3) the radar information obtained from the scope picture.

The output of the CIC system includes the radio and video reports to command, to combat air patrols, to surface units and other liaison links. These reports, which have been digested and integrated by the CIC officer from a tactical point of view,

contain certain information as to the number, position, speed and identity of the targets.

The CIC system consists basically of the CIC personnel with their respective skills and capacities, and certain specialized CIC electronic gear. The functions of the individuals within the system, when they are finally evolved and defined, will constitute the operational procedure and doctrine of the CIC. The complex system may be conveived as comprised of a number of simple sub-systems. A sub-system is a man-machine or a man-man link. When all the possible linkages in the CIC are considered operating as a single unit, the complexity of the CIC system can be appreciated. Before the total system can be understood, the capacities and potentialities of these sub-systems must be known. In this study a particular man-machine link is considered.

The total system may be capable of a number of functions. These functions are the CIC missions. The CIC system has been envisaged as capable of the following missions: airborne early warning, direct air interception, direct anti-submarine warfare, friendly submarine coordination, direct missile interception, strike direction, radar counter measures, PO link, communication relay, convoy control and coordination, air-sea rescue coordination, weather reconnaissance, and possibly others. For the purposes of our evaluation, we will limit our research to the study of AEW and air strike intercept, which have been considered, to date, as the primary CIC functions.

2. A Method of Evaluation

A method of evaluating a CIC system may be now considered. The evaluation of different CIC systems may be formulated in terms of a comparison of the effectiveness of alternate functional CIC systems in handling given problems according to certain established criteria of success. This means that the CIC system will be presented with a series of standardized problems and the responses, or output, will be observed. This output may be evaluated according to certain criteria. The criteria to be used in our studies were established after much discussion with tactically experienced consultants; they are to be time, accuracy, amount and quality. It can readily be appreciated that the system which can turn out the largest number of reports, with the greatest accuracy, in the shortest time, and of a superior quality for tactical purposes, may be considered to be the best system. The complex of man-machine links and operating procedures which constitutes the CIC system may be changed in various ways. Evaluating a CIC system, then means the testing of several alternate CIC systems against a series of standardized problems to compare the output from these alternate systems against objective criteria.

This orientation implies three main areas of research. The first involves the development of standardized tactical problems by means of which the alternative CIC systems may be tested. The second involves the development of alternative linkages and operating procedures for the PO-1W CIC system. The third phase

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involves comparing the performance outputs of the alternative systems according to specific criteria. It is with the problems which arise in the first area that this report is concerned.

3. <u>The Need for Basic Data</u>

This study deals with the first area of research described, namely, problem difficulty. Problem difficulty involves, in the main, a statement concerning the total load which is placed on a given system. Target load may be broadly defined in terms of two sets of variables: (1) space density, and (2) time density. Space density refers to the distribution of the targets over the scope face. Time density involves the total number of occurrences per unit time, including: (a) the new targets which come on the scope, (b) the fading and reappearance of old targets, (c) target course changes, and (d) the appearance or non-appearance of IFF signals. It is apparent that the work load on the operator increases with the number of targets which must be considered and with the number of events that occur per unit time.

This experiment deals essentially with the first variable, space density, which is considered here in terms of the number of targets on the scope. In studying this parameter, it is necessary to work, at first, with a single sub-system. This means studying the capacities and potentialities of an individual air control officer and his associated equipment. The researches are expected to yield: (1) the fundamental data on sub-system capabilities, and (2) the necessary data for obtaining some

concept of the difficulty of a problem in terms of space densities.

The above theoretical formulation furnishes a frame work about which a series of experimental researches are being planned. The results of the first of these researches are presented in the remainder of the report. It is expected that the data derived from this and subsequent researches will furnish the basic information necessary for a more complete system evaluation.

III. THE EXPERIMENTAL STUDY

The theoretical discussions concerning the over-all systems study indicated the need for certain kinds of information. The initial objective is to obtain data concerning the capabilities of the various sub-systems, and second, the factors which effect problem difficulty and equivalence. Throughout this report the approach to the limit of some capability of a sub-system is referred to as "saturation." Four factors are studied with respect to saturation limits. The experiment was designed to obtain fundamental data concerning the relationship which obtains between space density and (1) the detection time of new targets, (2) the number of reports of target information which could be made in a given unit of time, (3) the accuracy of direct unaided visual estimation of range, bearing, course, and speed of targets, and (4) the frequency with which the position of any target is marked. The measure of space density used in this study is the number of targets already on the scope face when the new target appears.

1. Description of Apparatus

The experiment was conducted in a mock up of the Cadillac III airplane. This full scale mock up simulates the part of the hull of a PO-1W airplane* into which the essential CIC electronic equipment of Cadillac III has been incorporated. The experiment was conducted on the IP-48 unit of the APA/56

*Manufacturer's Brief Model Specifications for the Lockheed Constellation Model 749 CIC Airplane; Lockheed Aircraft Corp., Report No. 6569, June 11, 1948 (Confidential).

remote radar indicator.*

The IP-48 is a 12" PPI repeater radar scope on which a number of different presentations may be obtained. For the purposes of this experiment, the controls were so set that the sweep length represented a 200 mile range, and the scope presented a polar grid with 10 mile range rings and 30° angle markers. Video gain was adjusted by the subjects to their personal preference. The hull was darkened to simulate actual operating conditions.

2. Target Simulation

In order to study the Cadillac III system in the laboratory, it was necessary to develop a method of electronically simulating the radar information which is ordinarily fed into the radar indicator. The Aircraft Target Generator 15-AM-1** was developed for this purpose.

Several target generators were used to provide the targets used in our study. They enabled the setting in of targets at some initial position; and they also allowed these targets to assume a pre-set course and speed.

A script was prepared beforehand to facilitate the running of each problem. The various manipulations necessary to simulate the problems were listed in a time sequence.

*Handbook of Maintenance Instructions for Indicator Assembly AN/APA-56 (XN-1); Bureau of Aeronautics, August 1, 1949, (Confidential).

**Target Simulator for Cadillac Evaluator: Device 15-AM-1; O.N.R., Special Devices Center, Report No. 42 (N8-2), November 14, 1949, (Confidential).

As much information as possible was pre-set into the simulator. After the start of each problem, it was necessary only to make those adjustments which were indicated by the script.

3. Instructions to Subjects

The subjects were told that targets would appear at random positions and times on the scope face and follow randomly selected courses. The subjects were instructed to report into a voice recorder the appearance of each new target as soon as it was detected. This detection report was to be given priority above any other. The range, bearing, course and speed of the target were to be reported as frequently as possible. All judgments with respect to range, bearing, course and speed were to be made by direct visual estimation, utilizing only the 10 mile range rings and 30° angle marks. The frequency of plotting was to be maintained at the subject's own option or convenience.

4. Description of Experimental Problems

In the construction of this experimental problem, consideration was first given to the practical tactical experience of airborne CIC personnel. On the basis of this information, it was decided that a thirty minute problem involving fifteen targets might be expected to tax the capabilities of the scope operators very heavily. The targets were introduced at irregular intervals of 30 seconds to 3 minutes. The first five targets were introduced within the first two minutes in order to build up the load quickly. The initial positions of the targets were randomly chosen points on the scope face. This does not simulate usual

tactical problems, but it has the advantage of permitting broader generalization from our conclusions. For the same reason, the courses and speeds of the various problems were chosen at random. Speeds varied between 100 and 600 knots. Course varied through 360°, being necessarily limited, however, to such courses which would keep the target on the scope face. The target tracks involved no course changes. Some idea of how the problem appeared to the experimental subject may be gained from Fig. 1. Table 1 gives the initial position, bearing, speed and course of each target.

Table 1
Target Characteristics

Target No.	Initial Position (miles from center)	Course (degrees)	Speed (knots)	Time of Appearance (min. : sec.)
1	S36 W148	045	475	00:00
2	N120 W72	135	350	00:30
3	N84 E12	070	260	01:00
4	S48 E12	255	400	01:30
5	N120 W96	090	560	02:00
6	N72 E72	270	250	03:00
7	S136 W12	315	200	06:00
8	S36 W48	060	325	07:00
9	S36 E84	230	150	09:00
10	N108 E48	270	500	12:00
11	N84 W96	170	410	14:00
12	N36 E144	260	350	15:00
13	S136 E120	320	370	17:00
14	N180 E24	210	230	18:00
15	N12 W168	100	420	20:00

The problem was prepared in four equivalent forms by rotating the original problem, described above, 90° clockwise in three successive steps. This procedure kept the time and spatial relations within the problem constant, but each presentation was

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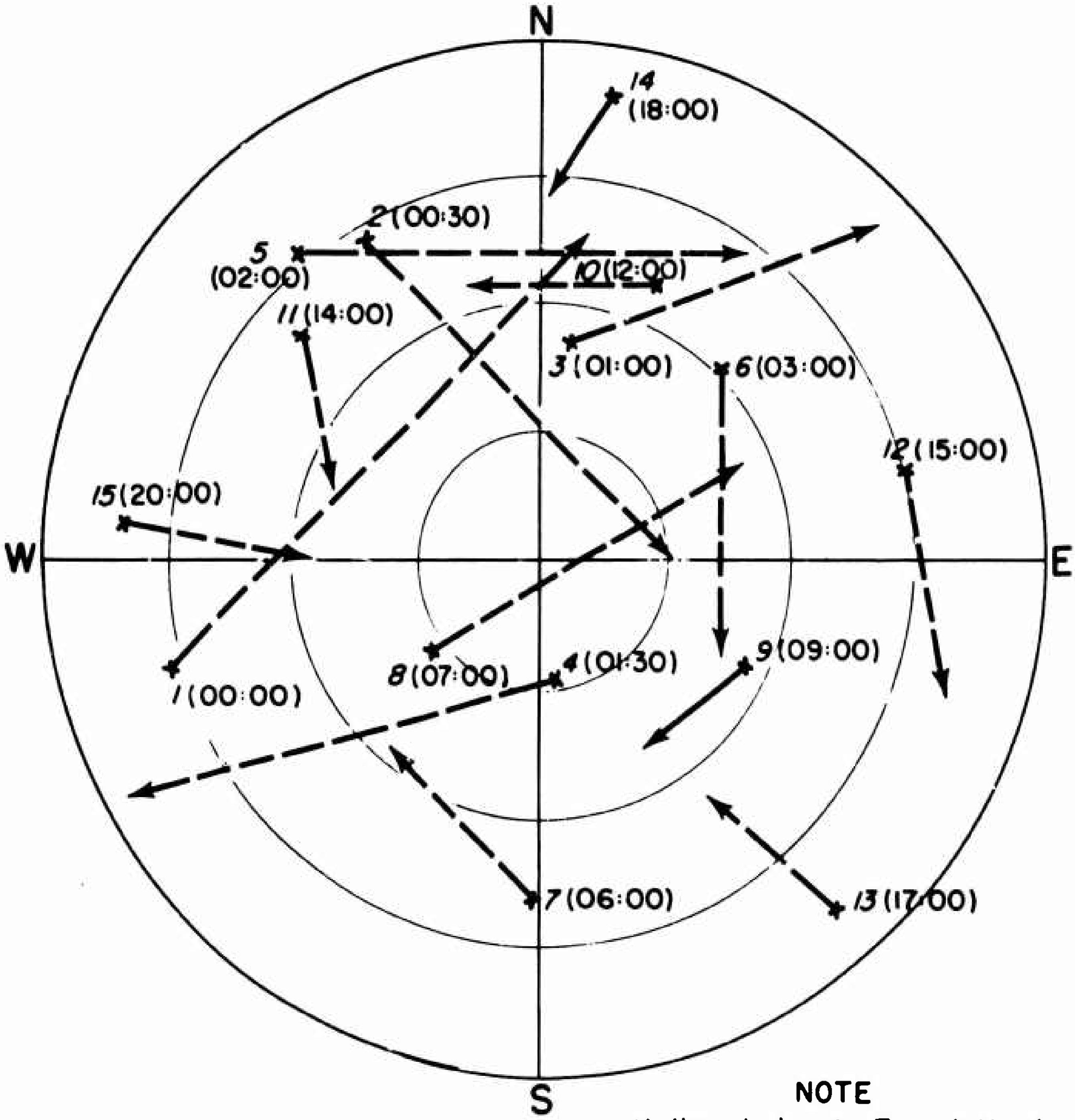

NOTE
Italics designate Target Number.
Parenthesis designate Time of
Appearance.

FIG. 1 — Schematic Representation of Problem I — Full Target Tracks

reoriented so that it was perceptually different each time. This perceptual difference was later confirmed; none of the subjects guessed that they had been working with essentially the same problem. The four replications of the experiment have been designated as Experiments 11.11, 11.12, 11.13 and 11.14, respectively. Two subjects were tested at a time on four successive days.

5. Subjects

The four experimental subjects studied here were naval officers, ranking from Ltjg. to Lcdr., with shipboard or airborne CIC experience. Before the experiment, the subjects became thoroughly familiar with the APA/56 gear, with which they had had no previous experience. The subjects were given one preliminary practice problem for familiarization with the problem, instructions, and procedures involved.

6. Recording of Data

It was necessary to have a record of both the subjects' responses and the problem as it appeared to them, in order to effect the desired measurements. These data were obtained by photographing the scope picture at every sweep, by complete recordings of subjects' verbal reports, and by direct observation of the subjects' plotting behavior.

The visual presentation on the scope face was recorded on a Fairchild camera which was set to take a picture of every sweep that was presented. This meant that six frames were exposed every minute giving a complete record of how the problem appeared

at any particular sweep during the problem. From such a record the actual bearing and course to the nearest degree, and range and speed to the nearest mile could be measured by projecting the image. This was necessary because there is always some error in both setting the problem into the target generator as well as in the generator itself. However, the camera records the problem as it actually appeared on the scope face and so becomes the most accurate record of the problem.

The second method of recording data utilized voice recordings. The verbal responses of each subject were recorded on a wire or tape recorder. These verbal reports were concerned with the detection of new targets, their range, bearing, speed and course. Also on those recordings, a time signal (the work "Mark") served to indicate the start of the problem and the insertion of each new target. This provided a time base on the voice recording from which the various measures were made, when the recordings were played back.

Finally, the plotting behavior was observed by an experimenter inside the hull who recorded each subject's plotting responses every other minute. In this way a 50 per cent time sample was obtained on each subject.

Since the primary data were collected first on camera film and voice recorders, it was necessary to transcribe the data to obtain a record in written form. This was accomplished by viewing the film record of the scope face on a Recordak micro film reader. By appropriate measurements, the range,

bearing, speed and course of the targets, as they actually appeared on the scope, could be determined. The voice recordings were transcribed by playing back the records and writing down the verbal reports of the subjects. These reports were timed to a tenth of a minute. Since one tenth of a minute corresponds to less than one sweep revolution on the scope face, the accuracy of the data is within one sweep revolution.

IV. RESULTS

The following sections present the basic data of this study. The results are presented in four sections corresponding to the functions studied: detection time, accuracy, reporting and plotting.

1. Detection Time of New Targets

The data presented in Table 2 and Fig. 2 represent the mean detection time for any given target as influenced by the number of targets previously introduced on the scope face.

Table 2
Detection Time of a New Target*

Number of Targets on Scope	Mean Detection Time of the New Target	Standard Error of the Mean	Standard Deviation
0	.1	.01	.1
1	.1	.01	.1
2	.1	.01	.1
3	.2	.01	.2
4	.2	.01	.2
5	.1	.01	.2
6	.3	.02	.3
7	.3	.03	.4
8	.4	.02	.3
9	.5	.03	.3
10	1.0	.06	.7
11	.9	.05	.7
12	1.3	.08	.9
13	1.3	.08	.9
14	1.4	.43	1.4

*All data are in minutes.

The data presented represent the mean detection time for different numbers of targets already on the scope for all four subjects,

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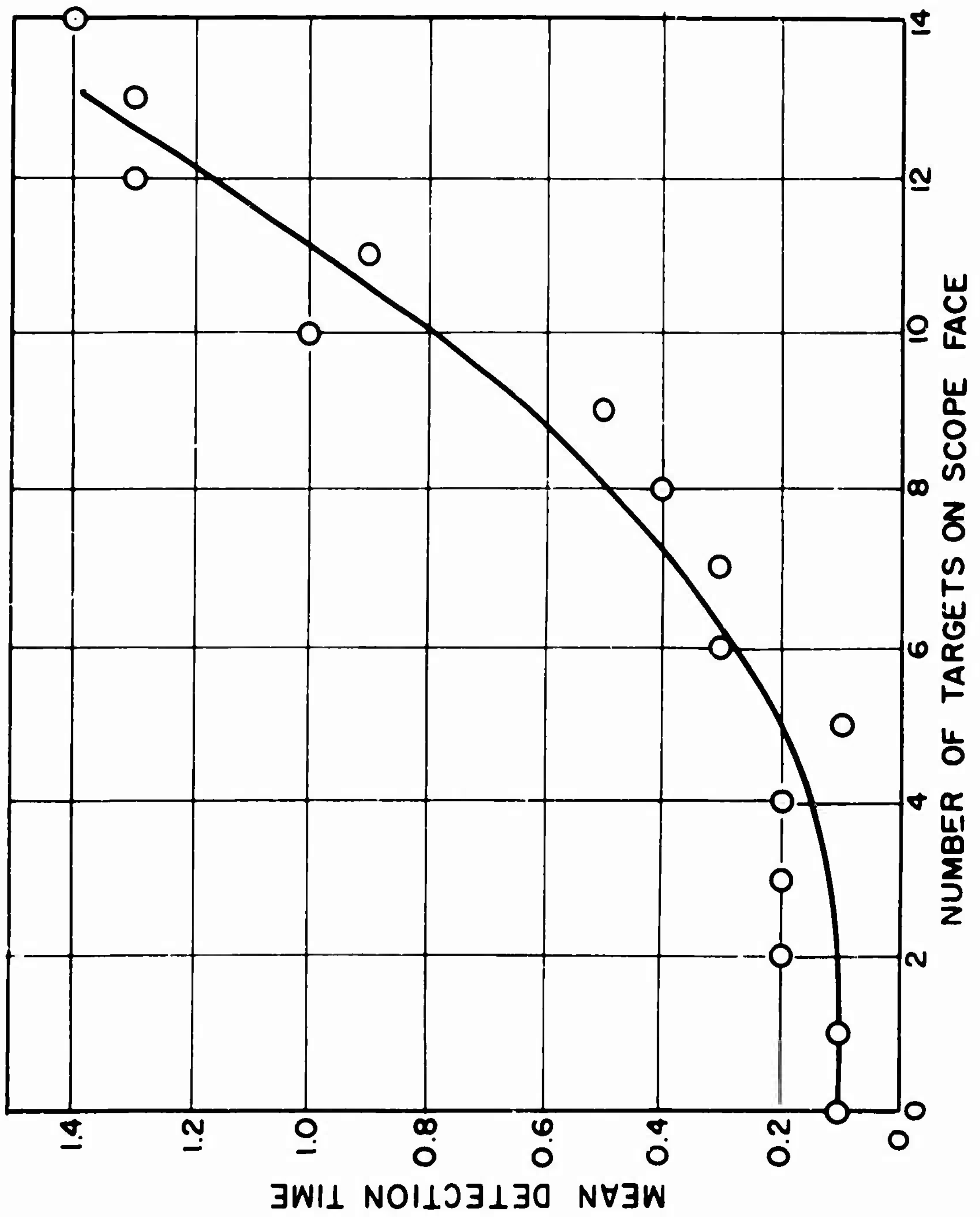

FIG. 2 — Detection Time as a Function of the Number of Targets on the Scope Face

with each subject having been tested four times. The standard deviations and standard errors are also presented.

2. Accuracy of Estimations of Target Characteristics

The accuracy of the estimation of target characteristics is revealed by the errors made in judging target range, bearing, course and speed. These errors were found by taking the difference between the reported positions and the actual or true positions of the targets. Errors may be considered from two points of view: relative error and absolute error. Relative error considers the magnitude and sign of the deviations; absolute error considers the magnitude only. The mean relative error gives a measure of the constant error of over or under estimation. The standard deviation of the relative errors is an inverse measure of the precision of estimation. The median absolute error is a measure of the accuracy of the estimates without respect to the direction of the error.

The errors which resulted under the conditions of this experiment are reported in Tables 3, 4 and 5. The data represent average values for all subjects for all runs.

a. Bearing Errors.

The frequency of the degrees of error for relative and absolute errors is given in Table 3 and Fig. 3. It was found that the mean relative bearing error was 0.53° with a standard deviation of 2.58°; the median absolute bearing error was 1.76°. Ninety-five per cent of the errors did not exceed 6.25°. Absolute bearing error as a function of number of targets on the scope is given in Fig. 6.

Table 3
Errors of Bearing Estimation

Error in Degrees	Frequency of Errors: Relative Errors	Frequency of Errors: Absolute Errors
10	10	16
9	8	11
8	11	16
7	18	27
6	20	27
5	58	75
4	62	85
3	117	192
2	201	339
1	275	478
0	538	538
-1	203	
-2	138	
-3	75	
-4	23	
-5	17	
-6	7	Median 1.8
-7	9	
-8	5	Q_3 3.0
-9	3	
-10	6	Q_1 .8
	Mean 0.5	Interquartile Range 2.2
	Standard Deviation 2.6	Total Errors 1804

b. Range Errors.

Range errors were treated similarly. The frequency distribution of range errors with respect to sign is given in Table 4. The relative mean range error is 1.85 miles, and the standard deviation is 2.17. The absolute range error frequency distribution is given in Table 4 and Fig. 4. The median absolute range error is 2.49 miles. Ninety-five per cent of the range estimates showed an error of less than 6 miles. The relationship between absolute range errors and the number of targets on the scope is presented in Fig. 6.

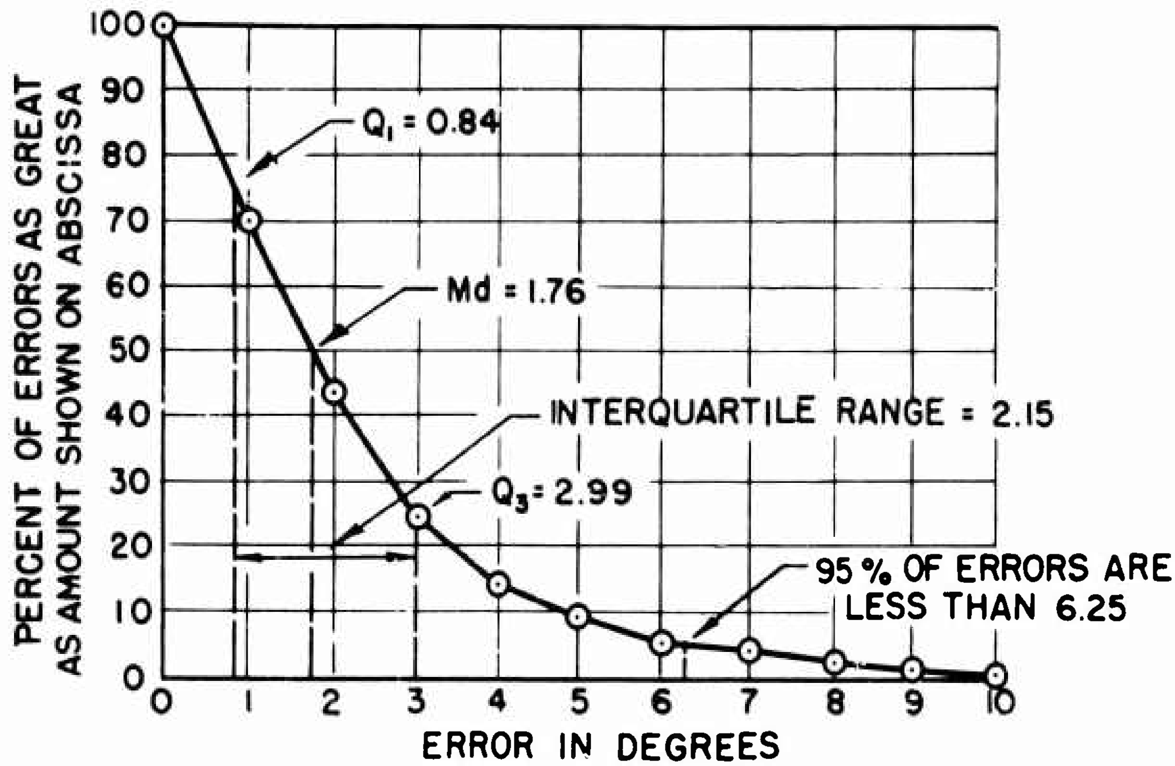

FIG 3- Absolute Bearing Errors

c. Course Errors.

The distribution of relative course errors is given in Table 5. The mean relative course error is 1.13°, and the standard deviation is 11.95°. The absolute course error frequencies are given in Table 5 and Fig. 5. The median absolute course error is 5.83°, and 95 per cent of the errors are less than 28.5°.

d. Speed Errors.

The estimations of the speed of the targets were in such gross error that the data were not given extensive statistical treatment. The average error in speed estimation showed an under estimation of 130 knots per hour. The range of absolute errors in speed estimation extended from zero to 350 knots per hour.

[redacted]

Table 4
Errors of Range Estimation

Error In Miles	Frequency of Errors: Relative Errors		Frequency of Errors: Absolute Errors	
10	7		9	
9	4		6	
8	16		19	
7	12		17	
6	28		32	
5	70		76	
4	143		150	
3	282		298	
2	473		499	
1	291		347	
0	253		253	
-1	56			
-2	76			
-3	16			
-4	7			
-5	6			
-6	4		Median	2.5
-7	5			
-8	3		Q_3	3.6
-9	2			
-10	2		Q_1	1.5
	Mean	1.9	Interquartile Range	2.1
	Standard Deviation	2.2	Total Errors	1706

3. Number of Reports Made

A report, as defined here, is any information unit on a target, such as bearing, range, course, or speed. The data were analyzed with respect to the number of reports made within a minute interval as the experiment progressed. The findings are presented in Fig. 7. Since the number of targets on the scope is also a function of time, this variable has also been plotted on the abscissa.

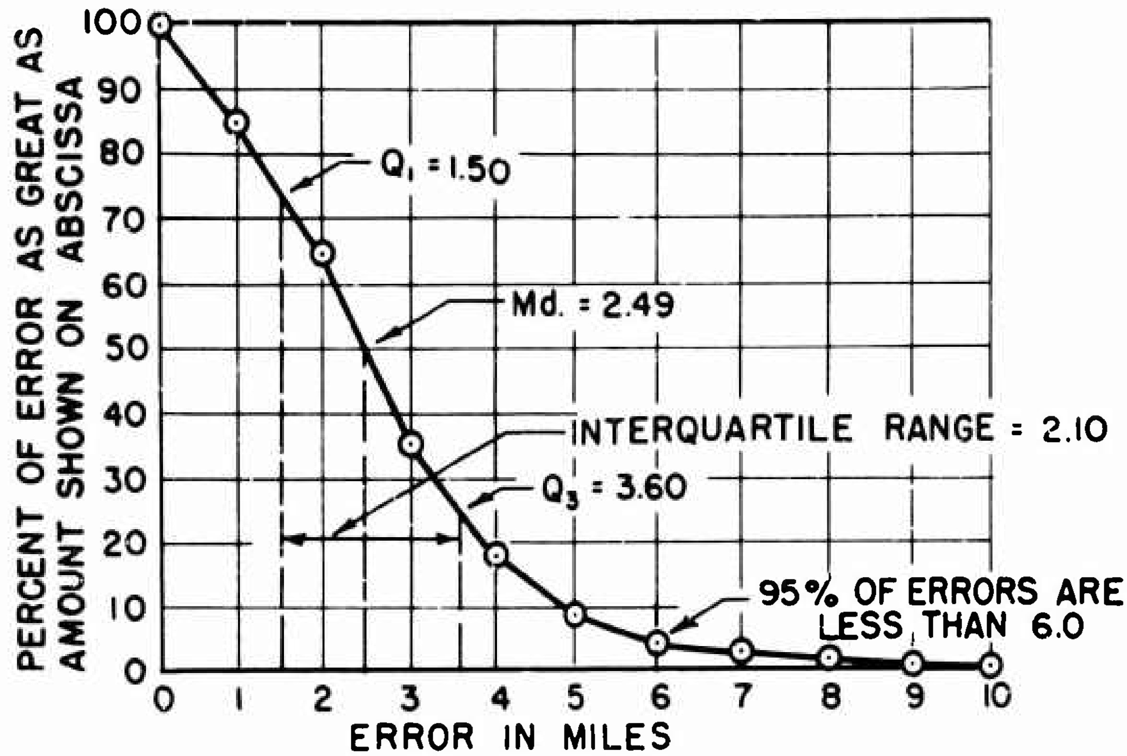

FIG. 4 - Absolute Range Errors

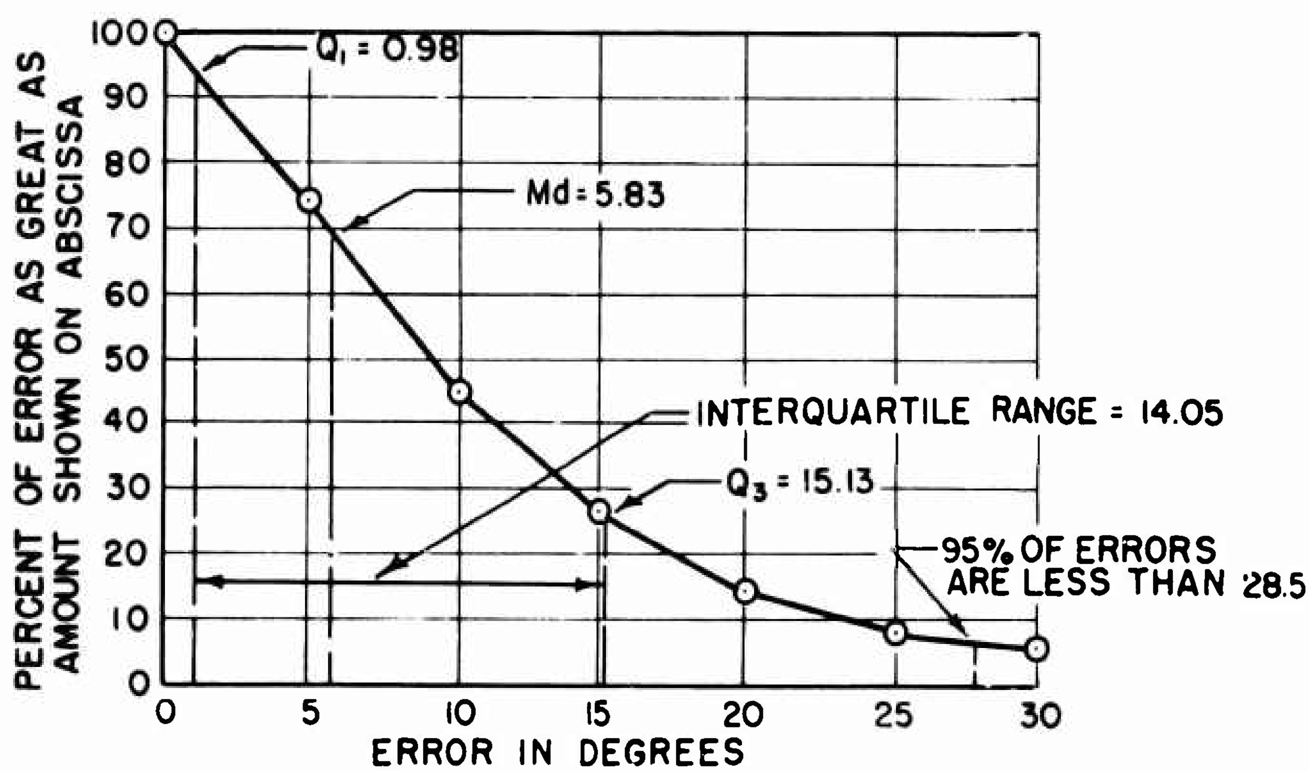

FIG 5 - Absolute Course Errors

Table 5
Errors of Course Estimation

Error in Degrees	Frequency of Errors: Relative Errors	Frequency of Errors: Absolute Errors
30	8	11
25	2	3
20	3	12
15	14	23
10	16	33
5	35	53
0	47	47
-5	18	
-10	17	Median 5.8
-15	9	
-20	9	Q_3 15.1
-25	1	
-30	3	Q_1 1.0
	Mean 1.1	
	Standard Deviation 12.	Interquartile Range 14.1

Another way of inspecting the number of reports made is by considering the time between successive reports for a given target. Targets 1, 5, and 10 were considered as a sample. The time between successive reports on these targets, considered with respect to the number of targets on the scope face, is presented in Fig. 8.

4. Plotting Behavior

From the time samples taken of the plotting behavior of all subjects on all experiments, the mean number of plots per minute was calculated. These data, plotted as a function of running time, are presented in Fig. 7. The grand mean number of plots per minute is 5.26.

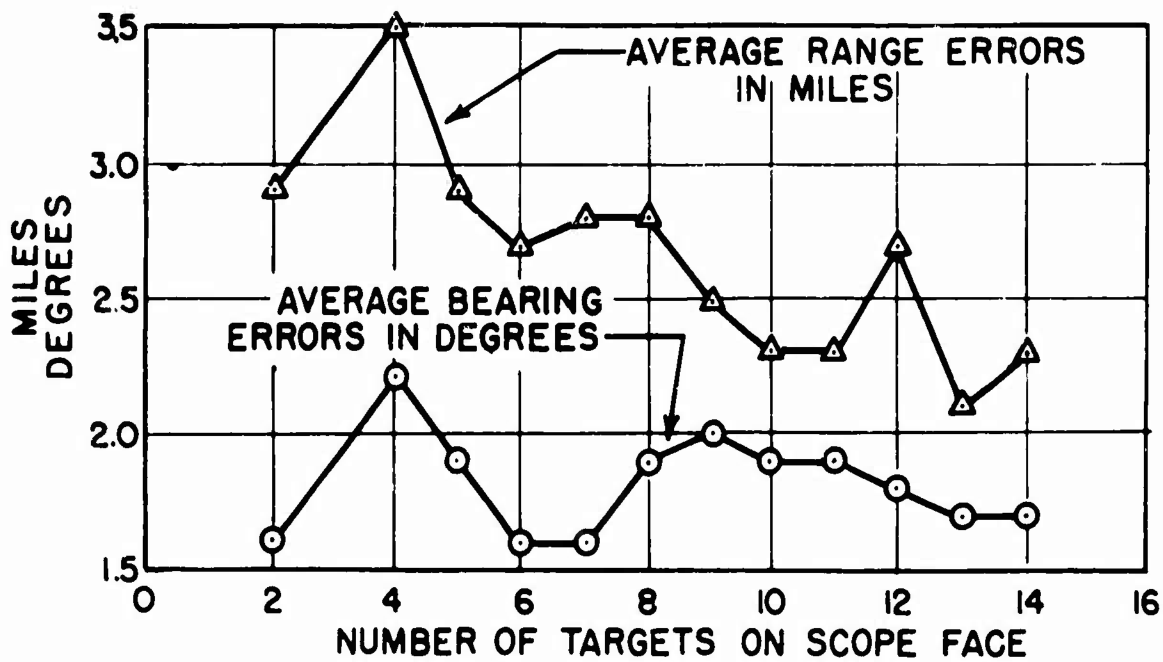

FIG. 6 - Bearing and Range Errors as a Function of the Number of Targets on the Scope Face

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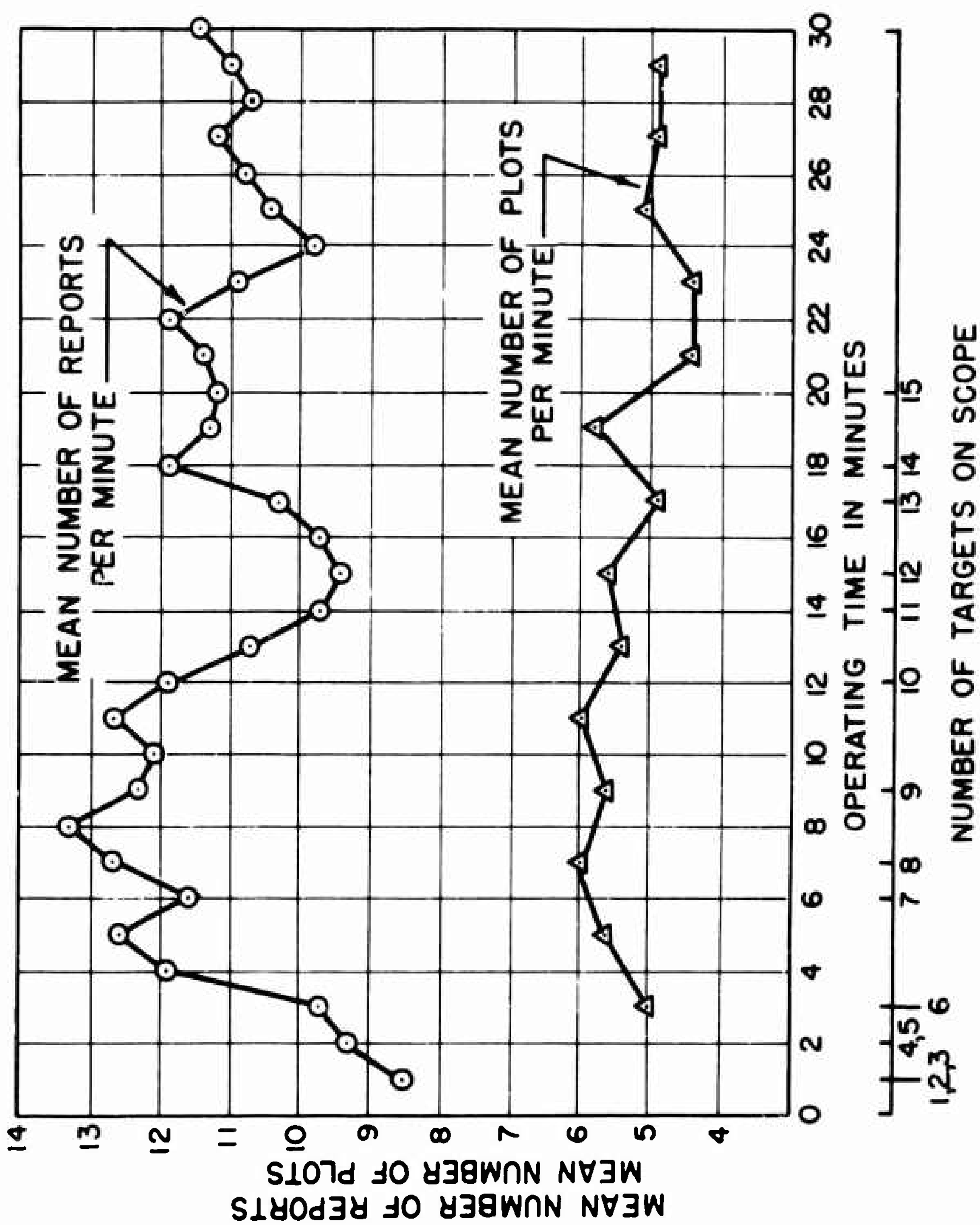

FIG. 7 — Number of Reports per Minute and Number of Plots per Minute as a Function of Operating Time

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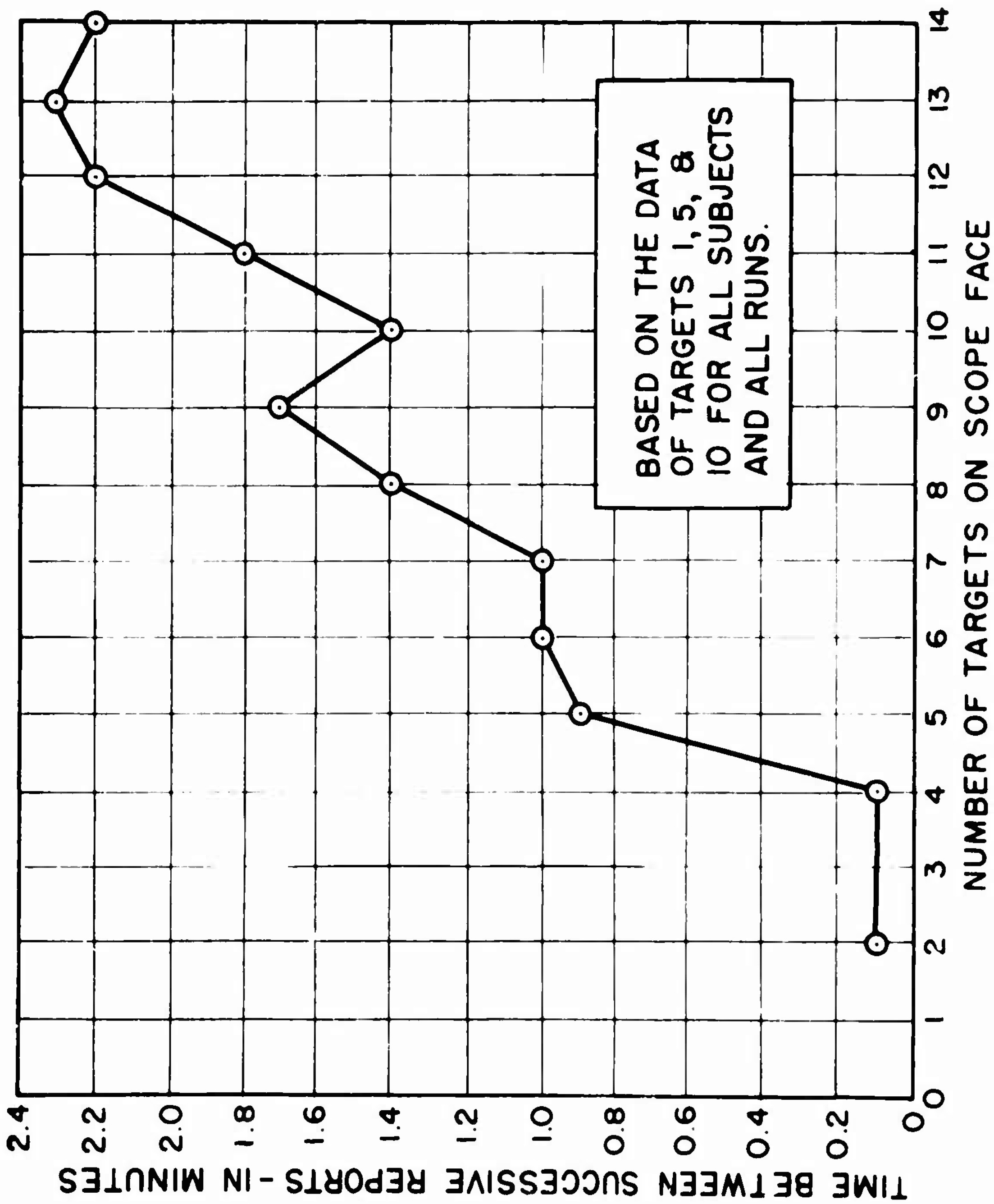

FIG. 8 – Time Between Successive Reports on a Given Target as a Function of the Number of Targets on the Scope Face

V. DISCUSSION

1. Detection Time of New Targets

In an AEW operation, the primary function of CIC is the detection of new targets. The problem which was raised earlier was: How is this detection time affected by the presence of a number of targets and their plotted tracks already on the scope? The data show very clearly that as the number of targets already on the scope increases, the detection time for a new target also increases as a positively accelerating function. The more targets on the scope, the longer it takes to detect a new target.

Stated in terms of the difficulty of the subjects' task, these data signify that as the number of targets present on the scope face increases, it becomes progressively more difficult to perceive and report the appearance of a new target. On the average, it takes 0.1 min. to detect and report a new target appearing on a previously blank scope; 0.14 min. to pick up and report a new target in the presence of four "old" ones; and 1.35 min. to observe and report an additional target when 14 targets are already on the face of the CR tube. The saturation level of an operator with respect to detection time can only be considered in relation to certain criteria of operational performance. If the upper time limit required for target detection and reporting is specified, the conditions, in terms of number of targets on the scope, under which the limit may be met, can be found in Fig. 2. If a detection time of one minute is required, no more than 11 targets can appear on the scope face when a single operator searches with a

centered presentation. If there are 14 targets on the scope face, it will take 1.35 min. to detect a new target.

While the subjects reported that they might be able to handle more than 15 targets, the work load was high, putting the operators under a great deal of stress. Qualitative analysis of the data indicates that with more than ten targets on the scope a certain amount of confusion arises with respect to detecting and numbering the targets. Target 13 may be detected and designated prior to target 12: and in addition, target 14 may be confused with target 11, and so on.

2. <u>Errors in Estimation of Target Characteristics</u>

Information concerning errors in the estimation of range, bearing, course and speed of targets is another area of investigation which might give some insight into the capabilities and potentialities of the men and machines involved in the system being studied. Two aspects of this problem are of particular interest. First, it is important to learn what the errors are in the direct visual estimation of target characteristics when the judgments are essentially unaided. The data obtained under this condition may then serve as a standard against which to evaluate experimental conditions which include the use of newly developed operational aids, such as the range and bearing strobes incorporated into the APA/56.

Second, the question arises as to whether a point of saturation may also be indicated by a decrease in accuracy in reporting the various target attributes under study? Such saturation

would be another indication of a limitation in the capacities of a single operator and his associated equipment.

a. Range and Bearing Accuracy.

Consideration of the data (Tables 3 and 4, and Figs. 3 and 4) on the accuracy of range and bearing shows that the errors of estimation are small and stable. From the results it may be expected that 95 times out of 100 the errors in range will not exceed 6 miles, and 6 degrees in bearing in either direction. The negligible size of the errors of the estimations and the stability of the judgments would seem to indicate that under certain conditions it might be entirely feasible to give such estimations within certain limits of accuracy without the use of mechanical or electronic devices. This would make for both a saving of time in obtaining target information, and a simplification in the operation and design of the gear.

The effect of increasing the number of targets on the scope on the accuracy of estimations of range and bearing is indicated in Fig. 6. These data indicate that increasing the number of targets has no deleterious effect on these activities. In fact, there appears to be some improvement. It would appear that these judgments do not suffer when the work load is increased. No saturation limit with respect to these functions can be said to have been reached under the conditions of this experiment.

b. Course Accuracy.

Without respect to the direction of the error, the median course error was about 7.5°. This is considerably greater than estimation of bearing given above. The variability of these estimations was also much greater: the sigma of the relative course errors being 11.95°. It would seem, then, that the accuracy of unaided estimation of course may not give the precision necessary for certain types of operations, e.g., vectoring CAPs, but may be adequate for work in which rougher and less reliable estimates are satisfactory.

c. Speed Accuracy.

Inspection of the raw data reveals gross errors in speed estimation. For the most part, the speed of the targets was underestimated. With respect to this function, direct estimation is too unreliable and inaccurate without some aid such as the three minute rule. Another study, to be reported elsewhere, indicates, however, that accurate direct estimates of speed may be possible with some training of the observers.

3. Number of Reports Made

Since the task of an AEW combat information center is not complete until the information which has been collected is disseminated, it is of great interest to learn something about the reporting behavior of the subjects.

Graphic demonstration of the data concerning this behavior is presented in Fig. 7. The shape of the curve resembles closely the general shape of a work or fatigue curve. The oscillating nature of the curve seems to indicate periods of high work output followed by periods of low output or relative rest periods. The curve oscillates around eleven reports per minute.

The subjective reactions of the operators indicate that they were under considerable stress and tension, and quite fatigued. Qualitatively, it was of interest to note that the initial decrement, occurring between the 10th and 16th minute interval, was accompanied by confusion in detecting the targets in the correct successive order. In the opinion of the experimenter, additional targets and lengthening operation time would have seriously disrupted the performance of the operators.

Since the sweep makes six revolutions per minute, and, on the average, eleven reports were made per minute, it appears that slightly less than two reports were made per sweep. This usually manifested itself as a joint report on range and bearing or course and speed of a given target. From this information it may be deduced that when there are considerably more than 6 targets on the scope, each target cannot be reported as often as once per minute.

In order to check this deduction, the data were considered from another point of view. The time between successive reports for a given target was tabulated and considered with respect to the number of targets on the scope face. These data are presented

in Fig. 8. It can readily be seen, as was to be expected, that as the number of targets to be reported increase, the time between successive reports on a given target increased. When there are 8 targets to be reported, a criterion of one report per minute of each target cannot be met.

4. Plotting Behavior

Since it is necessary to have not only current information on the target, but also to have some past history in order to estimate the course and speed of the target, plotting of the target is necessary to keep a record of that target. Plotting behavior was consequently observed to get some information on this function. The results showed very clearly that the differences among operators was significant; some individuals plotted consistently with a frequency as low as 3 plots per minute and others as high as 7 plots per minute. On the average, 5.26 plots were made per minute for all subjects. This means that about one plot was made for every scan of the radar sweep. This behavior was very consistent and showed no decrement with time as is indicated by Fig. 7.